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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY
ANNUAL REPORT

January 1993 - December 1993

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 20th year of station operation (January 1993 to December 1993).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 20 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1650 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-22]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters Measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved, and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (fecal and E. coli)

In mid February 1993 the sampling protocol was modified. Samples were no longer collected at Station 3 located in the mixing zone and, in addition, analysis of samples for ortho and total phosphates, iron and fecal coliform and E. coli were discontinued at all locations. This modified sampling regime continued through mid May when the original sampling protocol was reinstituted.

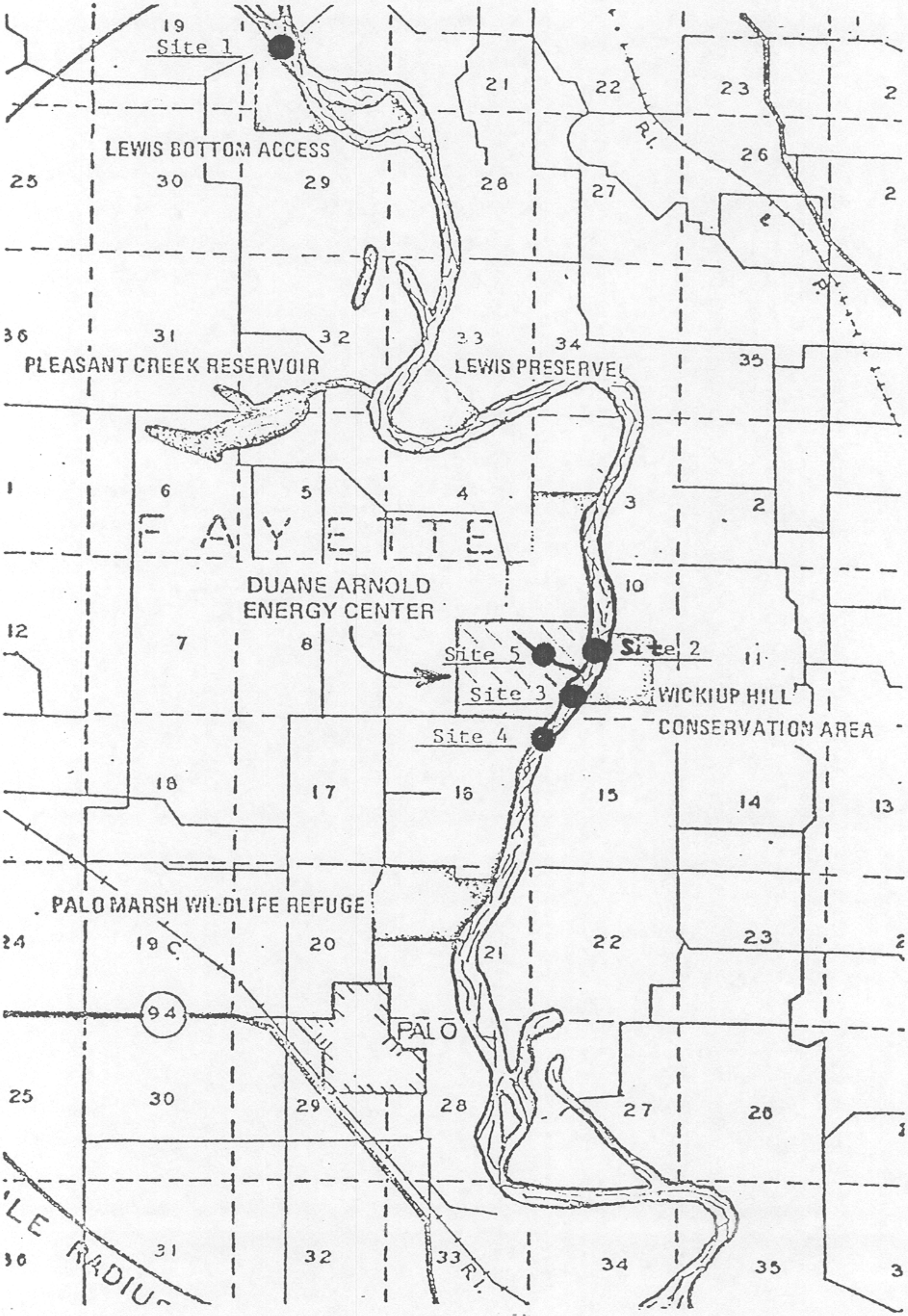

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly

B. Locations: at all five stations

C. Parameters Measured:

1.	Chromium	5.	Mercury
2.	Copper	6.	Zinc
3.	Lead	7.	Chloride
4.	Manganese	8.	Sulfate

III. Biological Studies

A. Benthic Studies:

1. Benthic studies were not conducted due to the extremely high river flows present in 1993.

B. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

C. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: yearly in 1993 due to high river flow
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

River flows during 1993 were, by far, the highest observed since the study was first implemented in 1972. Mean monthly discharges ranged from 155% of the 1961-1990 median monthly discharge in February to 1,166% in August. Estimated mean flow for the year was 15,900 cfs, three times greater than the average flow of 5340 cfs observed during the 22 year study. Mean monthly discharges at the Cedar Rapids gauging station ranged from 2537 cfs in February to 37,980 cfs in July. With the exception of February, mean monthly discharges were classified as excessive (greater than the 75% quartile throughout the year) and record mean monthly flows occurred from April through September.

January and February discharges were not unusually high ranging from a yearly low of 1940 cfs on February 27 to 6270 cfs on January 1. Flows increased sharply in late March reaching a yearly high and record April flow of 70,500 cfs on April 4 and then generally declined through May to 9050 cfs by May 27. Discharge again increased to 40,200 cfs by June 24 and varied from ca. 15,500 to 37,000 cfs through early July when flow again increased reaching a record July flow of 59,400 cfs on July 12. Flow generally declined in late July through mid August but again increased reaching a record August discharge of 55,200 cfs by August 21. Discharge generally declined from late August through December falling below 10,000 cfs by September 30, dropping to 5000 cfs by the end of October and continuing to decline to 1990 cfs by December 31. Hydrological data are summarized in Table 1.

<u>Temperature</u> (Table 2)

Ambient upstream river temperatures during 1993 ranged from 0.0°C (32.0°F) to 22.5°C (72.5°F). The maximum ambient (Station 1) temperature was observed on July 20 and August 16. This value was the lowest observed since the study was implemented in 1972 and well below the 1980 to 1992 average maximum of 26.8°C (80.2°F). Maximum downstream temperatures of 23.0°C (73.4°F) were observed at Station 3 and 4 also on August 16. The highest discharge canal (Station 5) temperature observed during the period was 25.0°C (77°F), which was recorded on June 15 and July 1. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 17.0°C (30.6°F) was observed on March 2.

Station operation continued to have a negligible effect on downstream water temperatures. The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 0.5°C (0.9°F) was measured on several occasions. Maximum temperature elevations at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) were also 0.5°C (0.9°F). Obviously there was no instance in which a temperature elevation in excess of the Iowa water quality standard of 3°C was observed. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values were the forth highest observed during the 22 year study period, but in spite of record flow still well below those present in 1991.[21] A peak value of 210 NTU occurred at upstream river locations in early July. Low values (3-6 NTU) occurred from January, through early March and in December. In contrast to most previous years, turbidity values in the discharge canal were usually higher than those observed in the upstream river. A maximum discharge canal turbidity of 390 NTU was observed on July 1.

Solids (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were slightly lower than those observed in 1991 and 1992.[21,22] Values ranges from 210 to 580 mg/L, with the majority falling between 350 and 400 mg/L.

Dissolved solids values were somewhat lower than those present in 1991 and 1992. Upstream values ranged from 120 to 400 mg/L. Values of less than 250 mg/L occurred at intervals in April, May, July and September. High values continued to occur in the winter. As in 1992, dissolved solids values at Station 3, 140 feet downstream of the discharge canal, were only slightly higher than values observed upstream, and differences were less obvious than those present in 1989 and 1990.[19,20] Maximum downstream values of 400 mg/L were observed at Stations 3 and 4 on January 6.

Suspended solids values at river locations continued to be relatively high in 1993 ranging from 3 to 290 mg/L. Low values occurred in January and February while highest values occurred during early July.

As in previous years, total and dissolved solids values in the discharge canal were much higher than in the river samples. Maximum total solids concentrations of 1800 mg/L were observed in the discharge canal in mid-June and October, while a minimum value of 340 mg/L was observed in mid August.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1993 were somewhat lower than those of 1992[22], ranging from 7.0 to 15.0 mg/L (80 to 106% saturation). Highest dissolved oxygen concentrations (ca. 12-15 mg/L) continued to occur in the river in winter when temperatures were low and the saturation value was highest. Lowest values occurred in July and August during a period of high runoff and very high river flow.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 5.3 to 11.8 mg/L (42 to 98% saturation).

Carbon Dioxide (Table 9)

Carbon dioxide concentrations in river samples were somewhat higher than those present in 1992[22], ranging from <1 to 5 mg/L. From late October through December values were below 1 mg/L. Maximum levels (4-5 mg/L) occurred in January, February, March, and July. Values in the discharge canal were frequently higher ranging from <1 to 19 mg/L.

Alkalinity, pH, Hardness (Tables 10-14)

These interrelated parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Average total alkalinity values in the 1993 river samples were generally lower than those present in 1991 and 1992.[21,22] Current values ranged from 94 to 244 mg/L. Lowest values occurred in early April accompanying extremely high river flows. Unlike the drought years of 1988 and 1989, lowest values did not occur during periods of low flow. Highest values occurred during January.

Carbonate alkalinity was not present in river samples from January through early October. A maximum value of 14 mg/L was observed in early November.

Values for pH in river samples were somewhat lower than those observed in 1992, ranging from 7.5 to 8.7. Highest values occurred from late October through December. As in previous years, highest levels accompanied increased photosynthetic activity while low values occurred during periods of runoff and high turbidity levels.

Total hardness values in the upstream river were higher than those present in 1992 and generally paralleled total alkalinity levels. The highest values (300-380 mg/L) occurred most frequently from January, through early March, and December, while low values of 110-125 mg/L occurred during a period of very high river flow in April.

Hardness values in the discharge canal continued to be consistently higher during periods of station operation than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 240 to 1,140 mg/L. Levels downstream of the station however were not generally higher than upstream values.

Phosphates (Table 15 and 16)

Total phosphate concentrations in river samples were generally similar to 1992[22] levels but peak values were higher in 1993. Concentrations in the upstream river ranged from <0.1 to 0.9 mg/L. High levels usually occurred during periods of high stream flow and runoff. Low values occurred in November and December. Levels in the discharge canal were consistently higher than those observed in the river. Discharge canal values ranged from <0.3 to 2.9 mg/L.

Orthophosphate concentrations in river samples were higher than those present in 1992 due likely to less uptake by the smaller algal populations present. Values ranged from <0.1 mg/L in the winter to 0.3 mg/L in the summer.

Ammonia (Table 17)

Ammonia concentrations in the river remained low in 1993 and were similar to those present in 1992.[22] Concentrations were below detection limits (<0.1 mg/L as N) from May through early December. High concentrations, 0.4 to 0.5 mg/L (as N) occurred in late March and early April.

Nitrate (Table 18)

Nitrate concentrations were similar to those present in 1992.[22] During the current year nitrate values in upstream river samples ranged from 2.3 to 8.6 mg/L (as N). Maximum levels (8.5-8.8 mg/L as N) occurred in early January. Minimum levels occurred in early April in conjunction with extremely high flow.

In contrast to some earlier years, nitrate concentrations were generally higher in the discharge canal than in river samples. A maximum nitrate concentration of 23 mg/L (as N) was observed in the discharge canal on May 19. Downstream nitrate concentrations were similar to upstream levels ranging from 2.4 to 8.6 mg/L (as N).

Iron (Table 19)

Iron concentrations in the river were generally similar to those present during 1992.[22] Concentrations ranged from 0.09 to 1.6 mg/L with a single extreme value of 9.8 mg/L. This maximum value was observed on July 1. Low values occurred in January. As in previous years, high iron concentrations were observed in association with increased turbidity and suspended solids, indicating that most of the iron present was in suspended form rather than in solution. Iron levels were consistently higher in the discharge canal during the current study. A maximum iron value of 18 mg/L was observed in the canal on July 1 but other values were far lower ranging from 0.17 to 4.1 mg/L.

Biological Studies

Biochemical Oxygen Demand (Table 20)

Five day biochemical oxygen demand (BOD_5) values were the lowest observed during the 22 year study ranging from <1 to 8 mg/L and, averaging 2.3 mg/L in 1993 as compared to 5.5 mg/L in 1992 (Table 26). Highest values occurred in early April in conjuction with extremely high flow. Lowest values, <1 mg/L, occurred in January and February. Unlike previous years when high BOD values, which appeared to be related to algal blooms were common, increased algal related levels were not observed during the 1993 study.

Coliform Organisms (Tables 21 and 22)

Coliform determinations included enumeration of both fecal coliforms as well as specific determination of *Escherichia coli*.

Coliform values were higher than those present in 1992.[22] Maximum river levels of fecal coliform and *E. coli* of 14,000 and 12,000 organisms/100 ml, respectively, were observed at the downstream location (Station 4) in mid August and high concentrations were common during periods of rainfall and high river flow in the summer. Low values of 50 or less organisms/100 ml were observed in early December. Fecal coliform and E. coli levels were not consistently higher in the discharge canal (Station 5) than at upstream locations. Maximum fecal coliform and E. coli concentrations of 8,100 and 6,300 organisms/100 ml, respectively, were observed in samples from the discharge canal on July 1.

ADDITIONAL STUDIES

In addition to the routine monthly studies a number of seasonal limnological and water quality investigations were conducted during 1993. The studies discussed here include additional chemical determinations, asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys, and impingement determinations.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 1 and July 1, 1993 from all river locations and from the discharge canal and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. With few exceptions, concentrations of all parameters fell within the expected ranges. Chloride and sulfate levels were low at all river locations on both sampling dates due likely to dilution by the very high runoff present. Levels of the heavy metals chromium, lead and mercury were below detection limits in all samples. Zinc concentrations in river samples ranged from 190 ug/L at the Lewis Access location (Station 1) on April 1 to <20 ug/L at the other river locations on the same date. Zinc values in the July river samples ranged from 40 to 60 ug/L. Manganese values were relatively high at all river locations ranging from 100 to 510 ug/L. Highest river manganese concentrations also occurred at the upstream location (Station 1) on April 1. Copper concentration ranged from <10 to 30 ug/L on April 1 to <50 ug/L on July 1. The high detection limits available for the July copper analysis made it impossible to determine if any were in excess of the chronic criteria for copper of 35 ug/L for class B waters.[23]

Reconcentration of solids in the blowdown discharge resulted in increased levels of chlorides, sulfates manganese and zinc in the discharge canal on both sampling dates. The high sulfate levels in the discharge canal on both sampling dates, 220 and 550 mg/L were also the result of the addition of sulfuric acid for pH control in the cooling water. The results of the additional chemical determinations are given in Table 23.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1993, as reported by Iowa Electric personnel, was the lowest observed since 1987.[17] Daily counts conducted by DAEC station personnel indicated a total of 384 fish were impinged during 1993. Highest impingement rates continued to occur during the winter and early spring period. During the months of January to April and in December 308 fish, or approximately 80% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred in June and July when only 3 fish were removed from the trash baskets. The month with the highest impingement rate was December, when 122 fish were collected in the trash baskets. The extremely low impingement numbers appear to be the result of the high river stage present during most of the year. The results of the daily trash basket counts are given in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In recent years a number of power generation facilities experienced problems with blockage of cooling water intake systems by large numbers of Asiatic clams (<u>Corbicula</u> sp.). Although this clam commonly occurs in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. <u>Corbicula</u> has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single <u>Corbicula</u> was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because <u>Corbicula</u> has been reported on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No <u>Corbicula</u> were collected during the 1981 to 1992 investigations.

The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. It is likely this clam entered the St. Lawrence Seaway from ships that used fresh water from Europe as a ballast and then dumped the water when they reached the United States. The zebra mussel has been a major problem in water intakes in Europe for many years and is now causing significant problems at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the Asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate.

Since its introduction into the United States the zebra mussel has rapidly expanded its range. It is now found in all of the Great Lakes and in 1991, just three years after they were first found in the U.S., they were collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers.[24] Although it was initially believed that the flood conditions present during 1993 might slow the advance of the mussel it is now apparent that the organism has established itself throughout the Iowa reach of the Mississippi River. Although it is impossible to make exact estimates, it is highly likely that the organism will continue to expand its range into the tributary streams of the Mississippi River within the next few years. If, or more likely when, it does colonize Iowa rivers, problems with intake structures at power plants in the area are likely to occur. As a result of these concerns, studies designed to detect the presence of the zebra mussel were first instituted in 1990. No zebra mussels were found during the 1990 to 1992 study.[20,21,22]

The high flows present in 1993 made it impossible to conduct detailed studies to determine the presence of either the Asiatic clam or the zebra mussel during the spring and summer of 1993. A single inspection for these forms was carried out in early October, 1993 at all sampling locations as well as between the bar racks and traveling screens at the intake structure. In addition visual inspections in the area of the discharge structure at the Pleasant Creek Reservoir were also carried out. No specimens of either specie were observed at any of the locations.

DISCUSSION AND CONCLUSIONS

During 1993 the Cedar River experienced the highest flows observed since the Cedar River Water Quality study was first implemented in 1972. Mean monthly discharges ranged from 2537 cfs in February to 37,980 cfs in July with a yearly mean flow of 15,900 cfs, three times greater than the average discharge of 5340 cfs present during the 22 year study. Even during years when river discharge was near or below normal the impact of station operation on the water quality of the river was minimal and impacts during the current year were almost nonexistent. In 1993 average temperatures at the downstream location (Station 4) during periods of station operation were actually slightly lower than those observed upstream (Table 25). Even during 1989, when mean river discharge was only 947 cfs, the lowest observed during the 22 year study, mean downstream temperature during periods of station operation was only 0.8°C (1.4°F) higher than upstream mean temperatures.[19] In 1992 when river discharge was near normal the mean temperature differential was only 0.2°C (0.4°F)[22]. In no instance were downstream temperatures greater than 0.5°C (0.9°F) above upstream temperatures observed during the 1993 study. Obviously no temperature differentials in excess of the 3°C (5.4°F) water quality standard[23] were observed during 1993. Other parameters such as dissolved solids, hardness, nitrates and iron which may be increased by reconcentration in the blowdown also exhibited little or no increase at the downstream location. The greatest observed increase in any parameter during the 1993 study was in dissolved solids with mean values of 305 mg/L and 319 mg/L at upstream and downstream locations respectively, an increase of only 14 mg/L (Table 25). This compares to mean increases of 49 and 12 mg/L during 1989 and 1992 respectively.[19,22]

During 1993 there continued to be no instances where an exceedence of the applicable Iowa Water Quality standards[23] were observed which could be attributed to the operation of the Duane Arnold Energy Center. Coliform concentrations of 500 and 12,600 organisms/100 mL respectively above background levels were observed on August 2 and 16 respectively at the downstream location (Station 4). However this high levels appear to be related to localized runoff rather than station operation since levels in the discharge canal and the mixing zone (station 3) were substantially lower.

Although the operation of the Duane Arnold Energy Center had a negligible impact on the water quality of the Cedar River the effects of the extremely high flows present were evident. Overall ambient water temperatures during 1993 were low. The maximum yearly ambient temperature of 22.5°C (72.5°F) observed in mid August was the lowest observed since the study was implemented in 1992. The cold rainy weather present during the summer of 1993 resulted not only in lower water temperatures but also impacted a number of other parameters as well. In contrast to earlier years, dissolved oxygen concentrations rarely exceeded saturation levels during the summer of 1993. These lower dissolved oxygen values resulted from reduced algal photosynthesis associated with the cloudy weather and extremely high river flows. Reduced photosynthetic activity also resulted in somewhat lower pH and BOD values during the summer. The 5 day BOD values were the lowest observed during the 22 year study period averaging only 2.3 mg/L as compared to 10.3 mg/L in 1989 when river flow was at record low levels and photosynthetic activity was high (Table 26).

As expected, suspended solids and turbidity values were relatively high during 1993 but did not equal the levels observed in 1991 when above normal flows were also present (Table 26). The continued rainfall and extreme flows present in 1993 apparently diluted the suspended material to levels somewhat lower than expected.

Average concentrations of other runoff related parameters such as phosphate, ammonia and nitrate were not unusually high during the period but total amounts of these substances present in the river in 1993 were substantially greater than those observed in most past years. This is readily apparent when the relative loading values, obtained by multiplying the average annual concentration by annual cumulative runoff, are compared (Table 27). It is obvious however that levels of phosphate and ammonia have decreased and nitrate concentrates have increased since the study was first implemented. These long term changes appear to be due to modifications in agricultural practices.

During 1993 a total of 384 fish were impinged on the intake screens at the Duane Arnold Energy Center. This is the lowest number observed since 1987 when 261 fish were impinged.[17] Impingement rates during the summer months were extremely low, a total of seven fish during the June-August period. These extremely low values are doubtlessly the result of the very high river stage present during the period.

In spite of extremely high river flows throughout the Mississippi River basin during 1993, the zebra mussel continues to expand its range and is now present throughout the Iowa reach of the Mississippi River. Although it has not yet been collected in the Cedar River it would be prudent to upgrade the current zebra mussel monitoring program in order to identify mussel infestation and institute appropriate control measures at the earliest possible time if the organism establishes itself in the Cedar River.

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Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1993

Date	Mean Monthly Discharge cfs	Percent of Median Discharge†
January	3195**	255
February	2537	155
March	10,330**	170
April	35,150**	523
May	18,310**	381
June	26,260**	483
July	37,980**	894
August	28,410**	1166
September	14,250**	650
October	6747**	273
November	4309**	175
December	3336**	176

*Data obtained from U.S. Geological Survey records
**In excess of the 75% quartile
†Based on 1961-1990 period.

Table 2

Temperature (°C) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

	Sampling Locations				
Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.0	0.0	1.5	0.0	0.0
Jan-18	0.0	0.0	0.5	0.5	0.0
Feb-03	0.0	0.0	5.5	0.5	0.5
Feb-18	0.0	0.0	1.0	-	0.5
Mar-02	1.5	1.5	18.5	-	1.5
Mar-18	0.5	0.5	2.0	-	0.5
Apr-01	5.5	4.0	8.5	-	4.0
Apr-15	5.5	6.0	10.0	-	6.0
May-06	13.5	13.5	13.5	-	13.5
May-19	13.5	14.0	18.5	14.0	14.0
Jun-03	13.0	13.0	21.5	13.0	13.0
Jun-15	20.5	21.0	25.0	21.0	20.5
Jul-01	19.0	19.5	25.0	19.5	19.5
Jul-20	22.5	22.0	24.5	22.5	22.0
Aug-02	21.0	21.0	23.5	21.0	21.5
Aug-16	22.5	23.0	23.0	23.0	23.0
Sep-01	19.5	19.5	18.0	19.5	20.0
Sep-13	19.0	19.0	19.5	19.0	19.0
Oct-07	15.5	16.5	18.5	16.5	17.0
Oct-20	12.5	12.5	23.0	12.5	12.5
Nov-02	4.5	4.5	10.5	4.5	4.5
Nov-16	5.0	5.0	7.0	5.0	5.0
Dec-01	2.5	2.0	12.5	1.5	1.0
Dec-16	3.0	3.0	6.0	3.0	3.0

Table 3

Summary of Water Temperature Differentials and Station Output During Periods of Cedar River Sampling in 1993

Date	ΔT(°C) Upstream River (Sta. 2) vs. Discharge (Sta. 5)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 3)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 4)	Station Output (% Full Power)
Jan-06	1.5	0.0	0.0	100
Jan-18	0.5	0.5	0.0	96
Feb-03	5.5	0.5	0.5	100
Feb-18	1.0	-	0.5	100
Mar-02	17.0	-	0.0	100
Mar-18	1.5	-	0.0	100
Apr-01	4.5	-	0.0	100
Apr-15	4.0	-	0.0	98
May-06	0.0	-	0.0	94
May-19	4.5	0.0	0.0	90
Jun-03	8.5	0.0	0.0	87
Jun-15	4.0	0.0	-0.5	83
Jul-01	5.5	0.0	0.0	79
Jul-20	2.5	0.5	0.0	74
Aug-02	1.5	0.0	0.5	0
Aug-16	0.0	0.0	0.0	0
Sep-01	-1.5	0.0	0.5	0
Sep-13	0.5	0.0	0.5	0
Oct-07	2.0	0.0	0.5	1
Oct-20	10.5	0.0	0.0	100
Nov-02	6.0	0.0	0.0	100
Nov-16	2.0	0.0	0.0	100
Dec-01	10.0	-0.5	-1.0	100
Dec-16	3.0	0.0	0.0	100

Table 4

Turbidity (NTU) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

Date 1993	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	4	3	7	4	4
Jan-18	3	4	4	4	4
Feb-03	5	6	40	5	6
Feb-18	6	4	7	-	7
Mar-02	4	6	33	-	5
Mar-18	24	15	22	-	16
Apr-01	65	62	120	-	62
Apr-15	20	20	20	-	20
May-06	23	24	12	-	24
May-19	30	28	61	31	26
Jun-03	56	46	89	49	27
Jun-15	120	120	270	120	120
Jul-01	210	210	390	210	190
Jul-20	120	110	290	100	100
Aug-02	87	83	75	84	84
Aug-16	110	96	8	90	97
Sep-01	59	61	7	61	54
Sep-13	36	37	27	30	36
Oct-07	32	32	19	32	29
Oct-20	20	20	48	21	20
Nov-02	11	12	19	12	12
Nov-16	7	8	7	7	7
Dec-01	5	5	4	5	5
Dec-16	6	6	6	6	6

Table 5

Total Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-06	440	440	1300	490	430
Jan-18	390	400	1100	420	400
Feb-03	400	420	1100	430	420
Feb-18	360	380	1400	-	400
Mar-02	400	390	1300	-	410
Mar-18	380	370	1200	-	370
Apr-01	210	220	740	-	210
Apr-15	370	390	380	-	370
May-06	380	*	680	-	350
May-19	390	390	1700	390	390
Jun-03	420	410	1600	420	410
Jun-15	500	460	1800	480	460
Jul-01	580	570	1700	560	570
Jul-20	390	400	1400	400	390
Aug-02	420	410	390	400	410
Aug-16	430	410	340	410	400
Sep-01	360	360	350	370	360
Sep-13	460	460	410	440	440
Oct-07	390	400	360	390	390
Oct-20	390	390	1800	480	390
Nov-02	380	380	920	370	370
Nov-16	350	350	1200	370	380
Dec-01	370	370	520	400	390
Dec-16	390	390	1400	360	390

*Lab Accident

Table 6

Dissolved Solids (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	380	380	1200	400	400
Jan-18	360	350	980	360	360
Feb-03	370	400	1000	380	390
Feb-18	340	350	1300	-	360
Mar-02	330	380	1100	-	380
Mar-18	290	280	1000	-	290
Apr-01	150	120	580	-	140
Apr-15	310	300	300	-	320
May-06	190	*	610	-	300
May-19	310	310	1500	290	280
Jun-03	310	310	1300	330	300
Jun-15	260	280	1400	290	270
Jul-01	280	270	1100	240	280
Jul-20	240	230	1000	230	240
Aug-02	310	310	280	290	290
Aug-16	270	290	320	290	260
Sep-01	250	240	330	250	260
Sep-13	340	330	330	330	330
Oct-07	300	300	300	290	300
Oct-20	320	320	1600	400	340
Nov-02	260	310	840	290	320
Nov-16	330	330	1100	340	330
Dec-01	340	340	480	360	380
Dec-16	330	340	1300	360	380

*Lab Accident

Table 7

Suspended Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	6	6	11	5	9
Jan-18	6	4	4	4	5
Feb-03	8	6	38	8	9
Feb-18	4	3	5	-	4
Mar-02	4	8	90	-	9
Mar-18	36	18	22	-	28
Apr-01	50	110	110	-	74
Apr-15	26	22	20	-	30
May-06	38	39	14	-	31
May-19	57	51	80	56	53
Jun-03	90	78	110	82	78
Jun-15	170	150	300	150	150
Jul-01	290	270	500	170	260
Jul-20	110	110	290	120	110
Aug-02	130	120	100	120	120
Aug-16	150	140	11	140	120
Sep-01	84	82	5	84	68
Sep-13	62	67	42	65	64
Oct-07	71	72	36	67	68
Oct-20	35	34	67	36	35
Nov-02	26	27	27	24	23
Nov-16	11	14	7	12	12
Dec-01	8	8	7	9	10
Dec-16	8	8	5	9	8

Table 8

Dissolved Oxygen (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	13.0	12.7	7.2	12.5	12.6
Jan-18	12.6	12.4	8.2	11.4	12.2
Feb-03	12.7	12.0	5.3	12.0	12.0
Feb-18	13.1	13.0	9.7	-	13.0
Mar-02	13.6	13.0	8.8	-	12.8
Mar-18	12.5	12.5	10.1	-	12.1
Apr-01	10.2	10.3	8.8	-	10.0
Apr-15	11.3	11.6	9.9	-	11.5
May-06	9.6	9.5	6.4	-	9.6
May-19	9.2	9.0	7.2	8.8	9.1
Jun-03	9.6	9.8	8.1	9.7	9.7
Jun-15	7.5	7.8	7.2	7.8	7.7
Jul-01	7.7	7.5	7.2	7.5	7.5
Jul-20	7.0	7.1	6.1	7.0	7.0
Aug-02	7.5	7.4	7.6	7.4	7.5
Aug-16	7.4	7.5	6.7	7.5	7.5
Sep-01	8.4	8.4	7.0	8.3	8.2
Sep-13	9.8	9.7	9.1	9.1	9.8
Oct-07	11.8	12.2	10.0	13.1	13.2
Oct-20	11.6	11.7	8.3	11.6	11.6
Nov-02	13.9	14.3	8.1	14.1	14.2
Nov-16	13.8	14.1	11.6	13.0	14.4
Dec-01	14.9	14.6	8.8	14.6	15.0
Dec-16	14.2	13.3	11.8	12.9	13.2

Table 9

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	4	4	*	5	4
Jan-18	3	4	*	4	4
Feb-03	4	3	*	4	4
Feb-18	5	3	*	-	4
Mar-02	3	5	*	-	5
Mar-18	3	3	*	-	3
Apr-01	3	5	9	-	5
Apr-15	3	3	5	-	3
May-06	3	3	19	-	3
May-19	4	2	*	2	2
Jun-03	2	2	*	2	2
Jun-15	3	3	*	3	3
Jul-01	5	5	*	4	5
Jul-20	4	4	*	3	3
Aug-02	3	3	3	3	3
Aug-16	3	3	11	3	3
Sep-01	3	3	13	3	3
Sep-13	2	2	3	2	2
Oct-07	3	2	<1	2	2
Oct-20	<1	<1	*	<1	<1
Nov-02	<1	<1	13	<1	<1
Nov-16	<1	<1	*	<1	<1
Dec-01	<1	<1	2	<1	<1
Dec-16	<1	<1	*	<1	<1

*Unable to calculate

Table10

Total Alkalinity (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	242	244	190	240	240
Jan-18	240	242	190	234	238
Feb-03	224	224	210	236	232
Feb-18	242	232	240	-	190
Mar-02	222	218	158	-	224
Mar-18	186	186	124	-	188
Apr-01	100	94	160	-	96
Apr-15	177	178	160	-	176
May-06	180	182	214	-	180
May-19	204	194	142	196	216
Jun-03	186	188	98	186	186
Jun-15	174	176	146	174	170
Jul-01	158	156	114	154	154
Jul-20	136	136	144	138	142
Aug-02	168	170	166	174	168
Aug-16	146	144	204	146	138
Sep-01	162	164	214	162	164
Sep-13	226	226	226	240	244
Oct-07	204	206	204	214	216
Oct-20	230	234	134	232	236
Nov-02	230	232	206	226	224
Nov-16	228	224	182	212	230
Dec-01	234	238	224	234	232
Dec-16	230	230	150	228	230

Table11

Carbonate Alkalinity (mg/L-CaCO) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	<1	<1	<1	<1	<1
Jan-18	<1	<1	<1	<1	<1
Feb-03	<1	<1	<1	<1	<1
Feb-18	<1	<1	-	<1	<1
Mar-02	<1	<1	<1	-	<1
Mar-18	<1	<1	<1	-	<1
Apr-01	<1	<1	<1	-	<1
Apr-15	<1	<1	<1	-	<1
May-06	<1	<1	<1	-	<1
May-19	<1	<1	<1	<1	<1
Jun-03	<1	<1	<1	<1	<1
Jun-15	<1	<1	<1	<1	<1
Jul-01	<1	<1	<1	<1	<1
Jul-20	<1	<1	<1	<1	<1
Aug-02	<1	<1	<1	<1	<1
Aug-16	<1	<1	<1	<1	<1
Sep-01	<1	<1	<1	<1	<1
Sep-13	<1	<1	<1	<1	<1
Oct-07	<1	<1	2	<1	<1
Oct-20	6	6	<1	8	10
Nov-02	10	12	<1	14	14
Nov-16	6	6	<1	6	6
Dec-01	2	4	<1	2	2
Dec-16	2	2	<1	2	2

Table12

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	8.2	8.2	7.5	8.1	8.2
Jan-18	8.3	8.2	7.5	8.2	8.2
Feb-03	8.2	8.2	7.8	8.2	8.2
Feb-18	8.1	8.3	7.5	-	8.2
Mar-02	8.2	8.1	8.1	-	8.1
Mar-18	8.2	8.2	7.8	-	8.2
Apr-01	7.8	7.7	7.6	-	7.7
Apr-15	8.1	8.1	7.8	-	8.1
May-06	8.1	8.1	7.3	-	8.1
May-19	8.2	8.3	7.7	8.2	8.3
Jun-03	8.2	8.2	7.7	8.2	8.2
Jun-15	8.0	8.0	7.9	8.0	8.0
Jul-01	7.9	7.9	7.7	7.9	7.5
Jul-20	7.8	7.8	7.6	7.9	7.9
Aug-02	8.0	8.0	8.0	8.0	8.0
Aug-16	7.9	7.9	7.5	7.9	7.9
Sep-01	8.0	8.0	7.5	8.0	8.0
Sep-13	8.3	8.3	8.1	8.3	8.3
Oct-07	8.2	8.3	8.5	8.3	8.3
Oct-20	8.5	8.5	7.9	8.5	8.5
Nov-02	8.7	8.7	7.5	8.7	8.7
Nov-16	8.4	8.5	7.4	8.5	8.5
Dec-01	8.5	8.5	8.3	8.5	8.6
Dec-16	8.5	8.5	7.7	8.5	8.5

Table13

Total Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1993

	Sampling Locations				
Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	325	340	830	330	330
Jan-18	365	335	735	320	340
Feb-03	320	320	735	330	320
Feb-18	325	315	935	-	325
Mar-02	380	310	815	-	330
Mar-18	255	245	820	-	255
Apr-01	110	125	425	-	120
Apr-15	270	360	290	-	320
May-06	235	245	440	-	255
May-19	320	340	1140	350	350
Jun-03	275	280	935	370	290
Jun-15	240	310	920	215	240
Jul-01	230	290	760	250	250
Jul-20	175	185	710	180	190
Aug-02	235	250	240	220	235
Aug-16	185	205	270	200	205
Sep-01	190	210	270	200	210
Sep-13	325	325	300	295	295
Oct-07	280	260	270	280	265
Oct-20	305	290	1080	355	295
Nov-02	285	280	600	300	285
Nov-16	310	300	815	315	290
Dec-01	295	300	395	315	295
Dec-16	280	280	890	290	300

Table14

Calcium Hardness (mg/L-CaCO) Values for the Cedar River near the Duane Arnold Energy Center During 1993

	Sampling Locations				
Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	215	245	595	250	245
Jan-18	200	205	520	225	210
Feb-03	195	215	490	210	220
Feb-18	215	220	655	-	215
Mar-02	245	250	545	-	225
Mar-18	170	175	505	-	160
Apr-01	95	95	310	-	105
Apr-15	170	150	210	-	200
May-06	175	180	335	-	185
May-19	210	190	740	180	195
Jun-03	188	202	638	182	195
Jun-15	160	170	616	170	160
Jul-01	180	170	560	180	170
Jul-20	130	138	491	132	136
Aug-02	175	165	170	180	165
Aug-16	155	160	210	160	155
Sep-01	150	150	200	160	160
Sep-13	210	215	205	250	220
Oct-07	170	185	180	185	180
Oct-20	190	220	721	250	200
Nov-02	180	192	409	184	192
Nov-16	200	205	605	215	215
Dec-01	195	200	260	210	200
Dec-16	200	194	567	200	196

Table 15

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
	Sampling Locations				
Jan-06	0.2	0.2	0.7	0.3	0.2
Jan-18	0.1	0.1	0.6	0.2	0.1
Feb-03	0.2	0.2	0.8	0.3	0.2
Feb-18	-	-	-	-	-
Mar-02	-	-	-	-	-
Mar-18	-	-	-	-	-
Apr-01	-	-	-	-	-
Apr-15	-	-	-	-	-
May-06	-	-	-	-	-
May-19	0.2	0.2	1.7	0.2	0.2
Jun-03	0.5	0.5	1.8	0.5	0.4
Jun-15	0.9	0.8	2.7	0.8	0.6
Jul-01	0.5	0.5	2.4	0.6	0.5
Jul-20	0.3	0.4	2.6	0.4	0.4
Aug-02	0.3	0.3	0.6	0.3	0.3
Aug-16	0.4	0.4	0.9	0.4	0.4
Sep-01	0.3	0.4	1.5	0.3	0.3
Sep-13	0.2	<0.1	0.5	0.3	0.3
Oct-07	0.3	0.2	0.5	0.2	0.2
Oct-20	0.3	0.2	2.9	0.2	0.2
Nov-02	0.1	<0.1	0.6	0.1	0.1
Nov-16	0.1	0.1	0.8	0.1	0.1
Dec-01	<0.1	<0.1	0.3	0.1	<0.1
Dec-16	0.1	0.1	0.9	0.1	0.1

Table 16

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-06	<0.1	<0.1	0.3	<0.1	<0.1
Jan-18	<0.1	<0.1	0.2	<0.1	<0.1
Feb-03	0.2	0.2	0.4	0.2	0.2
Feb-18	-	-	-	-	-
Mar-02	-	-	-	-	-
Mar-18	-	-	-	-	-
Apr-01	-	-	-	-	-
Apr-15	-	-	-	-	-
May-06	-	-	-	-	-
May-19	<0.1	<0.1	0.7	<0.1	<0.1
Jun-03	<0.1	0.2	0.5	0.1	0.1
Jun-15	0.3	0.3	1.3	0.3	0.3
Jul-01	0.3	0.3	1.2	0.3	0.3
Jul-20	0.3	0.3	1.4	0.3	0.3
Aug-02	0.2	0.3	0.2	0.3	0.3
Aug-16	0.2	0.2	0.3	0.2	0.3
Sep-01	0.2	0.2	0.3	0.2	0.2
Sep-13	0.1	<0.1	<0.1	<0.1	<0.1
Oct-07	<0.1	<0.1	0.2	<0.1	<0.1
Oct-20	0.2	0.2	0.7	0.2	0.2
Nov-02	0.1	<0.1	0.5	0.1	0.1
Nov-16	0.1	<0.1	0.5	0.1	0.1
Dec-01	<0.1	<0.1	0.2	0.1	<0.1
Dec-16	0.1	0.1	0.8	0.1	0.1

Table 17

Ammonia (mg/L-N) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-06	0.1	<0.1	0.2	<0.1	<0.1
Jan-18	0.2	0.2	0.1	0.2	0.2
Feb-03	0.3	0.3	0.4	0.2	0.3
Feb-18	0.2	0.2	<0.1	-	0.2
Mar-02	0.3	0.3	0.3	-	0.3
Mar-18	0.5	0.4	0.3	-	0.4
Apr-01	0.4	0.4	0.1	-	0.4
Apr-15	0.2	0.1	<0.1	-	<0.1
May-06	<0.1	<0.1	0.1	-	<0.1
May-19	<0.1	<0.1	<0.1	<0.1	<0.1
Jun-03	<0.1	<0.1	0.1	<0.1	<0.1
Jun-15	<0.1	<0.1	0.2	<0.1	<0.1
Jul-01	<0.1	0.1	0.1	<0.1	<0.1
Jul-20	0.1	<0.1	<0.1	<0.1	<0.1
Aug-02	<0.1	<0.1	0.1	<0.1	<0.1
Aug-16	<0.1	<0.1	0.3	<0.1	<0.1
Sep-01	0.1	<0.1	0.4	<0.1	<0.1
Sep-13	<0.1	<0.1	<0.1	<0.1	<0.1
Oct-07	<0.1	0.1	<0.1	<0.1	<0.1
Oct-20	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-02	<0.1	<0.1	0.2	0.1	0.1
Nov-16	<0.1	<0.1	<0.1	0.1	0.1
Dec-01	0.1	<0.1	<0.1	<0.1	<0.1
Dec-16	0.2	0.2	0.1	0.2	0.2

Table 18

Nitrate (mg/L-N) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	8.5	8.6	10	8.8	8.6
Jan-18	7.0	6.9	11	7.2	7.1
Feb-03	6.9	7.0	12	7.2	7.1
Feb-18	6.0	6.6	12	-	6.6
Mar-02	6.2	6.3	14	-	6.5
Mar-18	5.2	5.2	11	-	5.4
Apr-01	2.3	2.3	4.7	-	2.4
Apr-15	6.3	6.4	4.7	-	6.4
May-06	6.6	6.8	2.9	-	6.8
May-19	6.8	6.6	23	6.7	6.8
Jun-03	7.7	7.5	19	7.5	7.5
Jun-15	7.1	7.2	21	7.1	7.1
Jul-01	6.7	6.6	14	6.6	6.6
Jul-20	5.6	6.0	15	5.7	5.7
Aug-02	6.4	6.2	5.9	6.1	6.3
Aug-16	5.0	5.3	0.3	5.2	5.0
Sep-01	5.1	5.0	0.3	5.0	5.0
Sep-13	6.3	6.3	5.3	6.3	6.3
Oct-07	6.1	6.0	5.0	5.9	5.9
Oct-20	6.6	6.8	21	6.9	6.8
Nov-02	5.9	5.8	6.2	6.0	6.0
Nov-16	5.8	6.0	9.9	6.0	6.0
Dec-01	5.9	5.9	6.4	6.1	6.1
Dec-16	5.9	6.0	12	6.1	6.0

Table 19

Total Iron (mg/L) Values for the Cedar River
near the Duane Arnold Energy Center During 1993

	Sampling Locations				
Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	0.09	0.09	0.40	0.10	0.10
Jan-18	0.09	0.10	0.22	0.12	0.12
Feb-03	0.14	0.15	0.90	0.18	0.18
Feb-18	-	-	-	-	-
Mar-02	-	-	-	-	-
Mar-18	-	-	-	-	-
Apr-01	-	-	-	-	-
Apr-15	-	-	-	-	-
May-06	-	-	-	-	-
May-19	0.98	0.75	1.9	0.85	0.78
Jun-03	0.80	0.68	1.5	0.70	0.53
Jun-15	1.6	1.4	4.1	1.4	1.4
Jul-01	9.8	9.6	18	9.9	9.4
Jul-20	0.91	0.86	3	0.88	0.88
Aug-02	1.3	1.3	1.3	1.3	1.3
Aug-16	0.92	0.81	0.39	0.81	0.75
Sep-01	0.68	0.69	0.69	0.69	0.62
Sep-13	0.73	0.72	0.66	0.73	0.74
Oct-07	0.47	0.44	0.36	0.43	0.43
Oct-20	0.37	0.32	1.0	0.31	0.33
Nov-02	0.18	0.18	0.54	0.19	0.18
Nov-16	0.25	0.15	0.46	0.16	0.15
Dec-01	0.12	0.15	0.17	0.14	0.13
Dec-16	0.13	0.13	0.35	0.14	0.13

Table 20

Biochemical Oxygen Demand (5-day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	<1	3	<1	1	1
Jan-18	<1	<1	<1	<1	<1
Feb-03	1	1	2	1	1
Feb-18	<1	1	<1	-	<1
Mar-02	1	1	2	-	1
Mar-18	3	2	4	-	2
Apr-01	8	8	8	-	7
Apr-15	<1	<1	<1	-	<1
May-06	7	3	2	-	3
May-19	2	2	5	2	2
Jun-03	3	2	3	2	2
Jun-15	2	2	7	2	2
Jul-01	2	3	3	2	2
Jul-20	1	1	3	2	2
Aug-02	2	2	2	2	2
Aug-16	2	2	<1	2	1
Sep-01	2	1	<1	2	2
Sep-13	1	2	1	1	2
Oct-07	4	4	3	4	4
Oct-20	3	3	14	3	3
Nov-02	3	3	1	3	3
Nov-16	2	1	<1	1	1
Dec-01	2	1	<1	1	1
Dec-16	2	2	1	2	2

Sampling Locations: columns 1–5 as headed above.

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1993

Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	250	190	<10	190	220
Jan-18	1300	1100	50	1400	810
Feb-03	360	320	580	400	260
Feb-18	-	-	-	-	-
Mar-02	-	-	-	-	-
Mar-18	-	-	-	-	-
Apr-01	-	-	-	-	-
Apr-15	-	-	-	-	-
May-06	-	-	-	-	-
May-19	270	210	330	140	260
Jun-03	610	600	640	500	610
Jun-15	2300	3700	850	1600	1700
Jul-01	5900	6600	8100	6700	5300
Jul-20	1300	1200	5100	1500	1400
Aug-02	5300	5000	2900	4900	5500
Aug-16	4600	4400	1600	5100	14,000
Sep-01	1000	1100	30	760	950
Sep-13	260	250	210	240	290
Oct-07	70	170	30	130	60
Oct-20	130	150	40	140	170
Nov-02	180	130	100	130	140
Nov-16	180	230	130	240	220
Dec-01	340	50	130	110	50
Dec-16	250	220	40	150	150

Table 22

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1993

	Sampling Locations				
Date 1993	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-06	260	160	10	110	180
Jan-18	1200	760	30	780	860
Feb-03	170	320	430	270	320
Feb-18	-	-	-	-	-
Mar-02	-	-	-	-	-
Mar-18	-	-	-	-	-
Apr-01	-	-	-	-	-
Apr-15	-	-	-	-	-
May-06	-	-	-	-	-
May-19	250	170	330	160	140
Jun-03	500	430	590	440	560
Jun-15	1800	2100	870	1300	1200
Jul-01	5600	4300	6300	4200	4400
Jul-20	850	1100	2100	800	1500
Aug-02	4500	3400	2200	3700	3100
Aug-16	3500	3400	700	2700	12,000
Sep-01	920	660	10	720	760
Sep-13	100	120	100	130	190
Oct-07	50	40	10	10	<10
Oct-20	70	110	10	130	70
Nov-02	<10	<10	50	<10	30
Nov-16	100	10	30	10	20
Dec-01	50	<10	10	<10	<10
Dec-16	100	100	<10	10	10

Table 23

Additional Chemical Analysis-1993

Station	Cl (mg/L)	SO^{-2} (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			Apr-01					
1. Lewis Access	8.5	11	<20	30	<10	510	<1	190
2. Upstream DAEC	8.5	11	<20	<10	<10	100	<1	<20
3. Downstream DAEC	-	-	-	-	-	-	-	-
4. One-half mile below plant	8.5	11	<20	<10	<10	100	<1	<20
5. Discharge Canal	30	220	<20	10	<10	310	<1	360
			Jul-01					
1. Lewis Access	14	20	<20	<50	<10	280	<1	60
2. Upstream DAEC	14	20	<20	<50	<10	280	<1	40
3. Downstream DAEC	14	20	<20	<50	<10	280	<1	50
4. One-half mile below plant	14	21	<20	<50	<10	270	<1	40
5. Discharge Canal	40	550	<20	<50	<10	670	<1	790

Table 24

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January-December 1993

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	1	0	0	0	0	0	0	0	3
2	1	0	1	0	0	0	0	0	0	0	0	1
3	1	4	3	0	1	0	1	0	0	2	2	9
4	1	2	1	0	0	0	0	0	0	1	0	11
5	0	0	1	0	0	0	0	0	0	2	0	13
6	3	1	2	0	1	0	0	0	0	3	0	8
7	0	0	0	0	0	1	0	0	0	5	0	6
8	0	0	4	2	0	0	0	1	2	1	0	5
9	0	2	3	0	1	0	0	0	0	0	3	4
10	0	0	0	0	2	0	0	0	1	2	2	4
11	0	0	2	3	0	0	0	3	0	0	0	0
12	0	0	3	4	0	0	0	0	1	0	0	3
13	0	4	7	0	1	0	0	0	1	0	0	2
14	0	4	9	0	1	0	0	0	0	0	1	1
15	0	1	10	1	0	0	0	0	0	1	1	6
16	0	3	17	2	0	0	0	0	0	0	0	11
17	1	2	14	3	0	0	0	0	0	1	3	4
18	0	0	7	2	0	0	0	0	0	0	0	4
19	1	1	4	0	0	0	0	0	0	4	1	3
20	0	0	4	1	0	0	0	0	0	1	2	2
21	0	1	2	1	0	0	0	0	0	1	0	5
22	0	2	1	0	0	0	0	0	0	1	0	4
23	0	0	4	0	0	0	0	0	2	1	2	1
24	2	1	1	0	0	0	0	0	0	2	2	1
25	0	0	6	0	0	0	0	0	0	0	2	1
26	0	0	1	0	0	0	0	0	0	0	0	1
27	3	1	1	0	0	0	0	0	0	0	3	0
28	0	1	1	0	0	0	0	0	1	0	1	0
29	0	-	2	0	0	1	0	0	0	0	0	4
30	1	-	5	2	0	0	0	0	0	0	0	0
31	2	-	0	-	0	-	0	0	-	1	-	5
Total	16	30	118	22	7	2	1	4	8	29	25	122

Annual Total 384

Table 25

Comparison of Average Values for Several Parameters at Upstream, Downstream, and Discharge Canal Locations at the Duane Arnold Energy Center During Periods Of Station Operation*-1993

Parameters	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Downstream (Sta.4)
Temperature (°C)	7.5	20.9	6.9 (88)
Dissovled Solids (mg/L)	305	1036	319 (105)
Total Hardness (mg/L)	287	751	288 (100)
Total Phosphate (mg/L)	0.27	1.4	0.25 (91%)
Nitrate (mg/L as N)	6.3	12.1	6.4 (102%)
Iron (mg/L)**	0.41	1.1	0.41 (100%)

*Percent of upstream level ()
** Excludes Jul 1 determination of 9.6 mg/L

Table 26

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1993

Year	Mean flow** (cfs)	Turbidity (NTU)	Total PO (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,375	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	0.30	1.5	10.3	224
1990	5,061	33	0.29	0.20	7.3	4.8	283
1991	8,085	65	0.38	0.20	7.9	4.3	268
1992	5,717	49	0.31	0.16	6.4	5.5	261
1993	15,900	44	0.27	0.16	6.2	2.3	276

*Data from Lewis Access location (Station 1)

**Data from U.S. Geological Survey Cedar Rapids gauging station

Table 27

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1993

Year	Mean Flow (cfs)	Cumulative** Runoff (in)	Turbidity	Relative Loading Values			
				Total PO	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74
1992	5,717	10.92	535	3.4	1.7	70	61
1993	15,900	32.39	1425	8.8	5.2	201	74

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station